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Toxics Use Reduction Case Study

GENTEX OPTICS ELIMINATES FREON USE IN CLEANING AND PRIMING OPERATIONS

BACKGROUND

Gentex Optics is the leading manufacturer of polycarbonate corrective and non-corrective eyewear for military, industrial and commercial markets. Gentex Optics was using Freon 113 in two lens processing steps. For many years, Freon 113 was a popular solvent because it was relatively inexpensive and highly effective. A major advantage of using Freon as a cleaning agent was that it did not require drying, so parts were ready immediately after cleaning for the next processing step.

The discovery that Freon was an "ozone depleting substance" (ODS), contributing to the destruction of the earth's protective ozone layer, led to regulations that banned the manufacture of Freon by January 1, 1996. Gentex Optics successfully developed a new aqueous system of cleaning and priming optical lenses. The replacement system has been found to be as effective, and in some cases *more* effective, than the Freon system it replaced. With the new process, Gentex is in compliance with all environmental regulations and has achieved significant increases in production.

TOXICS USE REDUCTION ACTIVITIES

CLEANING REPLACEMENT INVESTIGATION

Gentex began its effort to eliminate the use of Freon by investigating a number of alternative cleaners, including solvent cleaners, aqueous cleaning and aqueous cleaning in a centrifuge.

Perfluorocarbons (PFCs) were investigated as a possible drop-in replacement. However, they were very expensive (approximately \$300/gallon) and required expensive new equipment to minimize vapor losses. In addition, the cleaning effectiveness was not as good as Freon, especially for removing hydraulic oils. Availability was also an issue for Gentex.



Many of the solvents investigated were aliphatic hydrocarbons with high boiling points. While these solvent materials were relatively effective cleaners, they were difficult to remove from the parts. Heavy hydrocarbon-based liquids do not readily dry. Also, many of these materials were volatile organic compounds (VOCs) and contribute to air pollution.

Some solvents were not compatible with the polycarbonate lens process and attacked the surface and caused hazing. Other solvents looked promising, but the cost of equipment modifications and/or chemicals were too great. It became apparent that there was no drop-in replacement solvent for Freon that was suitable for the processes at Gentex Optics.

In 1992, Gentex investigated a detergent/water-based cleaning process using a centrifuge. Lenses were held on the outside wall of a spinning centrifuge drum while a detergent solution and subsequent rinse waters were sprayed from the center of the centrifuge. In this type of system, detergent and rinse water usage are minimized because of the dispensing method.

While the centrifuge process worked reasonably well, it did not meet the cleaning requirements for lenses. The detergent effectively cleaned the lenses, but was difficult to remove from the surface with a spray rinse. In addition, the rotational speed of the centrifuge was high (850 rpm) in order to spin dry the lenses. Some lenses could fly off during the spin cycle and lens racking was an issue. The centrifuge idea was abandoned because the batch cleaning process did not lend itself well to the volumes and flow of product at Gentex.

AQUEOUS CLEANING

Although initial efforts to find an alternative cleaner were unsuccessful, Gentex remained committed to eliminating the use of Freon in their manufacturing operations. Subsequently, they assigned the Research and Development Department the task of finding a suitable replacement. The task was divided between two groups within the department. The Process Development Group was charged with defining the process parameters for the new cleaning process. Since the data available was limited, assumptions were made and experiments were conducted to determine if the assumptions were correct. The Process Development Group proposed initial cycles and processing parameters. After the parameters and throughput were defined, the responsibility of the Manufacturing Engineering Group was to design and build a system that would provide the operation parameters specified. The proposed cleaning/priming system consisted of a detergent tank, a first rinse, a second rinse, a priming tank, rinse and an alcohol rinse. The times, temperatures and fluid quality levels all were specified. The Process Development Group continued experiments and investigations to further define and refine the process. Manufacturing Engineering was alerted anytime a process parameter changed significantly so that equipment could be modified accordingly.

CONTAMINANT DETERMINATION

Gentex knew from many years of experience that Freon cleaned the lenses quite well. However, when the company began to look at alternate cleaning methods, it became evident that the nature and amount of contamination were not sufficiently understood. Identifying and understanding the type of contamination being removed from the lens surface was of key importance in finding alternative cleaners. Microscopic examination of surface and coating defects became a top priority.

The contaminants found to be of concern for the cleaning process were airborne dust, hydraulic oil, finger prints and polycarbonate flash. Because they consist of oils and particles, fingerprints were found to be the most difficult contamination to remove.

DETERGENT SELECTION

After determining what contaminants had to be removed from the surface of a lens, the study of detergents began. A number of detergent samples from various sources were ordered and tested. Lenses were deliberately contaminated and subsequently immersed into a heated tank with ultrasonics. Upon removal from the detergent, the lenses were rinsed and examined. Detergent concentrations were initially adjusted to manufacturers' recommendations and then increased if found not to be effective at that concentration. In general, the strong alkaline detergents were less effective at removing mineral oil contamination. Increasing concentration did not improve cleaning efficiencies. Strong alkalines also left a residue on the polycarbonate surface which was more difficult to remove than the initial contaminant. Polycarbonate has a very active surface and attracted some of the inorganic compounds contained in the detergent. The most effective detergent found was relatively mild and readily removed fingerprints, mineral oils and dust. It was free rinsing, leaving no residue on the surface and did not interfere with the primer and coating adhesion or other critical coating performance requirements. The selection of the detergent was one of the most important steps to the success of the cleaning process.

RINSING

Having cleaned the lenses to remove initial contaminants, the lenses were now contaminated with detergent. Any detergent left on the lens interfered with the priming and coating processes. Rinsing the detergent must be done effectively and without recontaminating the optical surface. Tap water was found to have too many dissolved minerals and suspended particles. Therefore, two rinse tanks using filtered deionized water were used.

DRYING

One area of concern with aqueous cleaning was the problem of lens drying prior to coating. Ovens are often needed to dry the product after rinsing. However, because the surface tension between a clean polycarbonate lens and water is low, water readily beads off. By controlling the surface action of the rinse tank and the withdrawal speed of the lenses, only small droplets of water remained. Drying the lenses at room temperature proved to be sufficient to evaporate the remaining droplets. With this finding, the alcohol rinse was eliminated, further reducing VOC emissions.

AQUEOUS PRIMING

Lenses are primed after cleaning and prior to coating. For many years, Gentex had used Freon as a solvent in the priming process. The issues in developing a replacement were effectiveness and compatibility with previous and subsequent process steps.

The initial approach was to enlist the support of the coating manufacturer to develop a primer. Gentex requested that the manufacturer provide information on an alternative primer that would be compatible with the manufacturer's coating and the process, or else modify the coating to eliminate the need for priming.

The coating manufacturer determined that the coating could not be modified and decided that the easiest and fastest route to solve the problem was to develop a new primer. The route they pursued was to develop a urethane-based primer that was made up of 70 to 75% water (low VOCs were also a requirement of a new primer). While progress has been made in stability and processability of a urethane primer, as of September 1995, there were still processing and performance issues that made it unsuitable for production.

Other coatings that did not require a primer were investigated. Unfortunately, the chemistry of these coatings was not as benign because of solvents which attack the polycarbonate in order to obtain adhesion. Solvents such as methyl ethyl ketone were commonly used in these coatings. Because of the suspected carcinogenicity of these solvents, Gentex was very reluctant to pursue the commercial use of them. Testing also showed that these types of coatings did not have the processing and performance characteristics necessary for the production line.

Rather than rely on the coating manufacturer to solve the priming issue, Gentex investigated the use of other solvents as carriers for the primer. Ethanol initially was found to be the only solvent that would provide sufficient stability and effectiveness for the lens processing requirements. It was also compatible with the aqueous cleaning process because the lens did not have to be completely dry after being cleaned and the addition of deionized water from the rinsing was not detrimental to the primer. However, an Alcohol, Tobacco, and Firearms license was required to purchase and use the SDA 3A ethanol. Also, while an alcohol-based primer eliminated the Freon-based priming process, it was less stable and had high VOC emissions.

Gentex continued investigating aqueous primers and found one that could work with some process changes. The aqueous primer was found to be very stable and very effective, in fact, far more stable and effective than any priming process previously used. The cost of maintaining the aqueous primer is significantly lower than maintaining a Freon or an alcohol-based primer, largely because the costs to purchase, dispose and monitor emissions for Freon and alcohol were high. In addition, equipment costs for aqueous priming are lower because equipment does not need to be explosion proof, as it does with alcohol. Finally, because of its increased stability, the aqueous primer reduces down time, making the process more efficient.

TANK & FLOW MODIFICATIONS

After it had identified the aqueous cleaning and priming chemistry, Gentex found that the tank designs and filtration rates on equipment commercially available were inadequate for the aqueous system. These tank designs had "dead zones" where circulation was poor and particles collected, settled to the bottom and remained there almost indefinitely. The filtration rates on commercially available equipment were also found to be inadequate. Gentex designed their own tanks and flow patterns so that there were no dead flow regions to collect particles, including the bottom of tanks. This required a more complicated tank shape and configuration, adding slightly to

cost, although the manufacture remained relatively easy. Multiple input and output ports were installed to obtain adequate tank filtration turnover and ensure that there were no dead spots.

The first aqueous cleaning/priming system in full production use was carefully monitored to identify process problems. Experimental process changes were made on-line; some of the changes corrected problems while others did not. Among the improvements made:

- Further modifications to tanks to improve flow characteristics.
- Improved racking and handling of lenses.
- Improved access for routine maintenance.
- Improved air circulation and filtration.

CONCLUSIONS

Through its experience eliminating Freon and switching to an aqueous cleaning and priming system, Gentex discovered that there is a series of basic steps that companies should follow in the development of an aqueous cleaning process:

- First and foremost, determine exactly what your cleaning requirements are and what contaminants need to be removed from your parts.
- Determine if contaminants can be eliminated before cleaning is required.
- Determine what solvents or detergents will remove the contaminants. Investigate solvents and detergents recommended by the experts, but do not limit your studies to those alone.
- Determine what your equipment requirements must be and then demand that equipment manufactures provide it. (Current tank design, pumping and filtration, while adequate for Freon usage, most likely will be inadequate for aqueous-based cleaning.)
- If your cleaning requirements are critical, invest in the monitoring equipment (such as liquid and air particle counters) necessary to verify your process is working.
- Evaluate filters if they are critical to your process. While there are many good, high performance filters on the market, some have poor performance.
- Do not underestimate filtration turnover rate.

RESULTS

The total cost associated with the Gentex Dudley facility for conversion to aqueous cleaning and priming and the elimination of Freon was more than offset by the savings of hazardous waste disposal costs and higher production yields for one cleaning, priming and coating line. However,

some of this cost was associated with increased production requirements which would have been incurred anyway. The benefits to Gentex, however, have been significant:

- The process is far more efficient with water-based cleaning and priming. This includes a more stable process, higher yields and improved quality, and lower cost of processing materials.
- Gentex is in compliance with all environmental regulations while achieving significant increases in production.
- Finally, Gentex can stay competitive and remain in business, making lens products important to the marketplace.

*This case study is one in a series prepared by the Office of Technical Assistance (OTA), a branch of the Massachusetts Executive Office of Environmental Affairs. OTA's mission is to assist industry in reducing the use of toxic chemicals and/or the generation of toxic manufacturing byproducts. Mention of any particular equipment or proprietary technology does not represent an endorsement of these products by the Commonwealth of Massachusetts. This information is available in alternate formats upon request. OTA's **confidential, nonregulatory** services are available at **no charge** to Massachusetts businesses and institutions that use toxics. For further information about this or other case studies, or about OTA's technical services, contact: **Office of Technical Assistance, 100 Cambridge Street, Room 2109, Boston, Massachusetts, 02202; phone #(617)727-3260; fax #(617)727-3827; electronic bulletin board #(617)727-5621.***

